THE INCREMENTAL COST OF TRANSPORTATION CAPACITY IN FREIGHT RAILROADING

The Tennessee Valley Authority
Knoxville, Tennessee

and

The Center For Business and Economic Research
Lewis College of Business
Marshall University
Huntington, West Virginia

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The Tennessee Valley Authority (TVA) and the Center for Business and Economic Research (CBER) have prepared this report at the request of the U.S. Army Corps of Engineers. However, the material and analysis contained herein are those of the authors and do not necessarily represent the positions of TVA, the CBER, or Marshall University.

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EXECUTIVE SUMMARY

The Principles and Guidelines used by the U.S. Army Corps of Engineers to evaluate the economic benefits of navigation projects direct analysts to assume that competing transport modes have sufficient capacity to accept any diverted traffic unless there is clear reason to suspect otherwise. In most settings, there is no reason to challenge this assumption. In the case of the Upper Mississippi basin, however, current traffic volumes and projected traffic growth are such that even marginal diversions could place significant volumes of additional traffic on the nation's rail system. Consequently, to simply assume that rail carriers could absorb this traffic without increasing the rates charged to all shippers is imprudent. It is for this reason that the Corps of Engineers has engaged the Tennessee Valley Authority in a lengthy investigation of railroad capacity and incremental rail capacity costs in the Upper Mississippi Basin.

TVA's analysis has consisted of two phases. Initially, the theoretical underpinnings that lead profit-maximizing firms to add new transport capacity were carefully examined. Additionally, this first phase contained a pilot study intended to determine whether or not Geographic Information

Systems (GIS) data could be effectively employed to analyze line-haul railroad capacity. Using Federal Railroad Administration (FRA) traffic density categories as the dependent variable, an ordered probit model was constructed to statistically associate traffic density with network link characteristics. This novel application of GIS data proved remarkably successful. The configuration and physical characteristics of a specific segment of railroad trackage proved to be an extremely reliable predictor of traffic density as measured by the FRA. Consequently, the decision was made to proceed with a more extensive investigation of railroad capacity in the Upper Mississippi basin. The second phase was intended to not only associate railroad traffic levels with route characteristics, but also gage the cost of incrementally expanding current capacity in order to accommodate additional traffic. Additionally, the Phase II analysis was to provide an, at least, cursory consideration of potential traffic diversions and terminal capacity.

In order to obtain a continuous measure of railroad traffic nearly one-half million records from the Surface Transportation Board’s 1995 Carload Waybill Sample were routed over 75,000 distinct routings based on origin, destination, shipment length, and interchange locations. Once routed, associated car-loadings and predicted empty car movements were aggregated to measure the traffic on each of roughly 2,500 specific route segments. These cross-sectional traffic volumes were once again statistically associated with the characteristics of the trackage that supports them and, again, this association proved to be very reliable.

Given the continuous relationship between traffic levels and route characteristics, it is possible to identify the set of physical alternatives that will increase track capacity. The next step in the analytical process is then to determine which of these alternatives will yield the desired new capacity at the lowest cost. In order to assess the cost of infrastructure improvements, TVA consulted with civil engineers from the University of Tennessee’s Transportation Center. These engineers provided a generic set of costs for constructing or upgrading trackage to various standards under a number of different topographical conditions. In the final stage of the line-haul analysis these costs were combined with available alternatives to determine the incremental cost of line-haul capacity.

Unlike line-haul capacity, it is not possible to assess the potential of network terminals through cross-sectional statistical analysis. The capacity and limitations of each terminal are uniquely determined. Thus, a comprehensive analysis of terminal capacity would be both lengthy and expensive. In the current context, this sort of extensive analysis is not possible. This does not mean, however, that the matter of terminal capacity is ignored. Current traffic flows were combined with potential traffic diversions to identify those terminal locations that might expect to see the greatest amount of traffic growth in the event that barge transport on the Upper Mississippi becomes economically unfeasible. While a number of locations throughout the Mid-West, Gulf-Coast, and Pacific Northwest regions could expect to see incremental increases in railroad traffic, the location that would seem to be most effected is St. Louis. Because many rail routings to the Gulf of Mexico pass through the St. Louis area and because the option of transloading rail shipments to barge at St. Louis is economically attractive, the diversion of traffic off of the Upper Mississippi River could place considerable pressure on terminal facilities at that location. No other significant terminal problems were identified.

The results of the analysis suggest that accommodating all the current Upper Mississippi barge traffic on the nation’s rail system would require an incremental expenditure on capacity of between one-half and three-quarters of a cent per ton-mile. In order to assess the impacts of these costs on railroad rates it is necessary to compare incremental capacity costs to the capacity costs presently embodied within rail rates. Rail rates vary considerable across commodities and origin/destinations pairs. Currently unit train shipments of dry-bulk commodities move at between 1.5 and 4 cents per ton-mile, while rates for smaller shipments of higher valued commodities may earn revenues of 6 or 7 cents per ton-mile. For 1996, the average per ton-mile rate across all rail movements was roughly 4.5 cents. Rule of thumb estimates suggest that average fixed costs equal about one-third of the average rate or about 1.5 cents per ton-mile. Thus, it would appear that the average variable costs for large volume shipments are extremely low and that revenues from some shipments may not cover all costs. Of the roughly 1.5 cents in per ton-mile fixed costs, it is estimated that perhaps as much as one cent reflects the cost of line-haul and terminal facilities. Any further division of fixed costs is impossible within the current context. When estimated incremental capacity costs are compared to the capital costs currently embodied within railroad rates, it would appear that this new capacity would sometimes lower extant rates and sometimes necessitate their increase. These results do not, however, provide the irrefutable evidence necessary to forego the traditional assumption of adequate railroad capacity.

SECTION 1

INTRODUCTION AND MOTIVATION

Traffic predictions developed as a part of *the Upper Mississippi Navigation Feasibility Study* indicate that the demand for surface transportation in the Upper Mississippi basin may double or even triple over the next fifty years. The economic Procedures and Guidelines used by the U.S. Army Corps of Engineers (Corps) to determine project benefits and costs reason that if inland navigation capacity is not expanded to meet this new demand, competing surface transport modes either possess or will add the capacity necessary to accommodate the new traffic.[1] As a consequence, it is possible to assume that any quantity of any transportation alternative can and will be made available with no significant increase in its unit price. Benefits and costs are to be calculated accordingly. These same Procedures and Guidelines do, however, provide for the relaxation or revision of this capacity assumption if there is sufficient reason to do so.

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[1] See *Economic Principles and Guidelines for Water and Related Land Resources Implementation Studies*, U.S. Army Corps of Engineers, 1983, Section 2.6.11, p. 54.

In the specific case of Upper Mississippi basin navigation, there are several factors that have caused policy makers and transportation users to question the validity of the traditional assumption of available modal capacity - particularly with respect to rail transport. First, the volume of waterborne traffic projected to move to, from, and within the region is large relative to the traffic volumes currently observed on many other segments of the inland navigation system. Current Upper Mississippi tonnage is well in excess of 100 million tons each year. Further, both users and transportation planners are also concerned that the resurgence in rail traffic and rationalization of rail facilities evidenced over the past two decades has purged the rail system of the excess capacity that characterized the industry from the 1950s through the early 1980s. Industry publications are replete with stories describing current operational bottlenecks, related service problems, and railroad efforts to eliminate the conditions that currently constrain traffic.[2] Finally, some worry that the consolidations within railroading (from roughly two dozen Class I carriers in 1980 to as few as seven in 1998) have resulted in an industry that is incapable of responding to demand growth even if the economic incentives that would normally signal a need for new capacity are present.[3]

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[2] Certainly, both line-haul and terminal congestion on the Union Pacific has garnered press coverage. Additionally, however, it is worth noting that various railroads, including the Union Pacific are spending considerable sums to increase capacity and eliminate bottlenecks. For example, the Burlington Northern-Santa Fe recently spent more than $100 million to reopen the Stampede Pass route across the Cascade Mountains in Washington State. Both BNSF and the UP are triple-tracking segments of their routes leading from the Powder River Basin and Norfolk-Southern and CSXT have pledged more than $300 million in capital improvements if their acquisition and division of Conrail is successful.

If the typical capacity assumptions employed within the Corps methodology are inappropriate, the resulting analysis could significantly misstate the value of proposed navigation improvements. In particular, if rail carriers do not possess the capacity to accommodate diverted traffic; of if the cost of accommodation would increase overall rail rates, then the value of proposed navigation projects would be understated.[4] It is for this reason that the Tennessee Valley Authority (TVA) in conjunction with the St. Louis and Rock Island Districts of the U.S. Army Corps of Engineers has engaged in an 18-month examination of U.S. rail network capacity and incremental capacity costs.

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[3] As this document is being prepared, it is likely but not certain that the Surface Transportation Board will approve the transaction through which Conrail assets are to be acquired by and divided between Norfolk Southern and CSX Transportation. If this transaction is approved, the number of U.S. owned Class I railroads will be reduced to six. Additionally both the Canadian National and the Canadian Pacific Rail System maintain an operational presence in the U.S.

[4] See, *The Incremental Cost of Transportation Capacity in Freight Railroads, Phase I Analysis*, U.S. Army Corps of Engineers, St. Louis District, May, 1997.

The remainder of this document is organized as follows: Section 2 provides a general description of extant rail capacity, as well as a discussion of those factors that determine specific route capacities. A model for estimating line-haul route capacity is developed in Section 3 and estimation results are also discussed within that section. Section 4 combines model estimation results, data detailing railroad construction costs, and information of a few select terminal locations to develop estimates of incremental rail capacity costs in the Upper Mississippi basin. Finally, Section 5 concludes the document with a few summary comments.

SECTION 2

U.S. RAILROAD CAPACITY

2.1 OVERVIEW

In 1995, U.S. railroads operated roughly 150,000 miles of track over which they moved 1.8 billion tons of freight an average of 756 miles to provide a total of more than 1.345 trillion ton-miles of transportation services. Of this total more than 527 million tons originated and/or terminated in the Upper Mississippi basin. Summary traffic statistics are reported in Table 2.1 below.

Aggregate statistics, however, cannot be used to adequately evaluate the relationship between barge transportation and the potential need for additional railroad capacity. To the contrary, capacity issues must be investigated by fully disaggregating the rail network and evaluating the capacity of each of the “links” that, together, form specific routes. Both the need for and the complexity of this “link-specific” analysis are made clear through a simple example.

Figure 2.1 portrays a simple network comprised of six nodes (A, B, C, . . .) and six links (AB, AC, BC, . . .). Together, these links form no less than 24 distinct two-way routings. Traffic along such a

Table 2.1

STCC	ILLINOIS	IOWA	MINNESOTA	MISSOURI	WISCONSIN	TOTAL
1	21,172,956	13,363,797	11,551,723	6,586,894	5,413,400	58,088,770
8	348,660	29,560		16,200		394,420
9	39,880			2,000		41,880
10	3,031,784	47,520	15,259,701	299,200	14,529,984	33,168,189
11	61,150,343	26,104,427	24,448,259	44,176,352	37,561,580	193,440,960
13	1,420,936	7,800				1,428,736
14	8,812,472	4,011,028	1,954,232	852,804	895,648	16,526,184
19	1,470,153		13,480			1,483,633
20	23,037,453	5,671,500	2,790,063	4,379,644	1,120,700	36,999,360
21	5,200		173,112	3,960		182,272
22	202,476	44,720	187,440	158,376	6,520	599,532
23	830,348		4,760	6,960		842,068
24	8,004,479	2,879,121	1,956,700	2,375,678	2,456,528	17,672,506
25	495,980			257,960	47,320	801,260
26	10,817,292	1,403,126	2,686,580	1,370,560	4,237,168	20,514,726
27	232,784		252,968	69,760		555,512
28	26,823,149	6,316,850	6,160,940	5,117,816	2,642,252	47,061,007
29	6,079,610	1,963,243	1,254,357	825,855	776,497	10,899,562
30	447,014		110,792	53,360	3,080	614,246
31	1,027,888		2,080	113,520		1,143,488
32	3,671,566	1,398,048	2,786,120	1,258,412	1,707,208	10,821,354
33	6,357,716	1,749,358	2,047,637	1,276,364	586,432	12,017,507
34	115,372		3,800	48,160		167,332
35	710,200	39,660	1,631,364	6,360	7,840	2,395,424
36	630,100	70,280	536,140	131,424	800	1,368,744
37	14,605,627	1,165,220	1,184,384	2,374,798	484,200	19,814,229

STCC	ILLINOIS	IOWA	MINNESOTA	MISSOURI	WISCONSIN	TOTAL
38	531,096			8,160		539,256
39	1,893,121		10,400	26,320		1,929,841
40	4,203,668	661,732	507,964	537,128	673,120	6,583,612
41	281,880		29,560	201,964	10,840	524,244
42	2,291,547	167,552	159,360	376,992	37,680	3,033,131
43	108,920	4,960		19,560		133,440
44	519,720		170,768	37,560		728,048
45	207,704		218,796	9,560		436,060
46	19,684,427	460,572	1,232,904	2,168,816	253,680	23,800,399
47	342,740			30,440		373,180
48	316,616			268,740		585,356
Grand Total	231,922,876	67,560,074	79,326,384	75,447,657	73,452,477	527,709,467

network could readily move from A to B, from B to F, or from C to E. There are, in fact 15 distinct origin destination pairs that are served by this network. Moreover, in nine cases, there is more than one way to connect a particular pair of points. For example, it is possible to route from A to D by simply going from A to C to D. Alternatively the AC link may be avoided by a routing from A to B to C to D.

It is not sufficient, however, to confine the analysis to individual routes. Even a cursory examination of the network pictured in Figure 2.1 indicates that a number (15) of the specific routes utilize the CD link. Thus, it is impossible to evaluate the capacity necessary over the CD link simply by measuring the traffic that moves from C to D or from D to C. It is also necessary to consider the need to move traffic from B to E, from A to F, etc. Thus, an accurate evaluation of U.S. rail capacity requires an examination of tens of thousands of potential routings over several thousand individual rail network links.[5]

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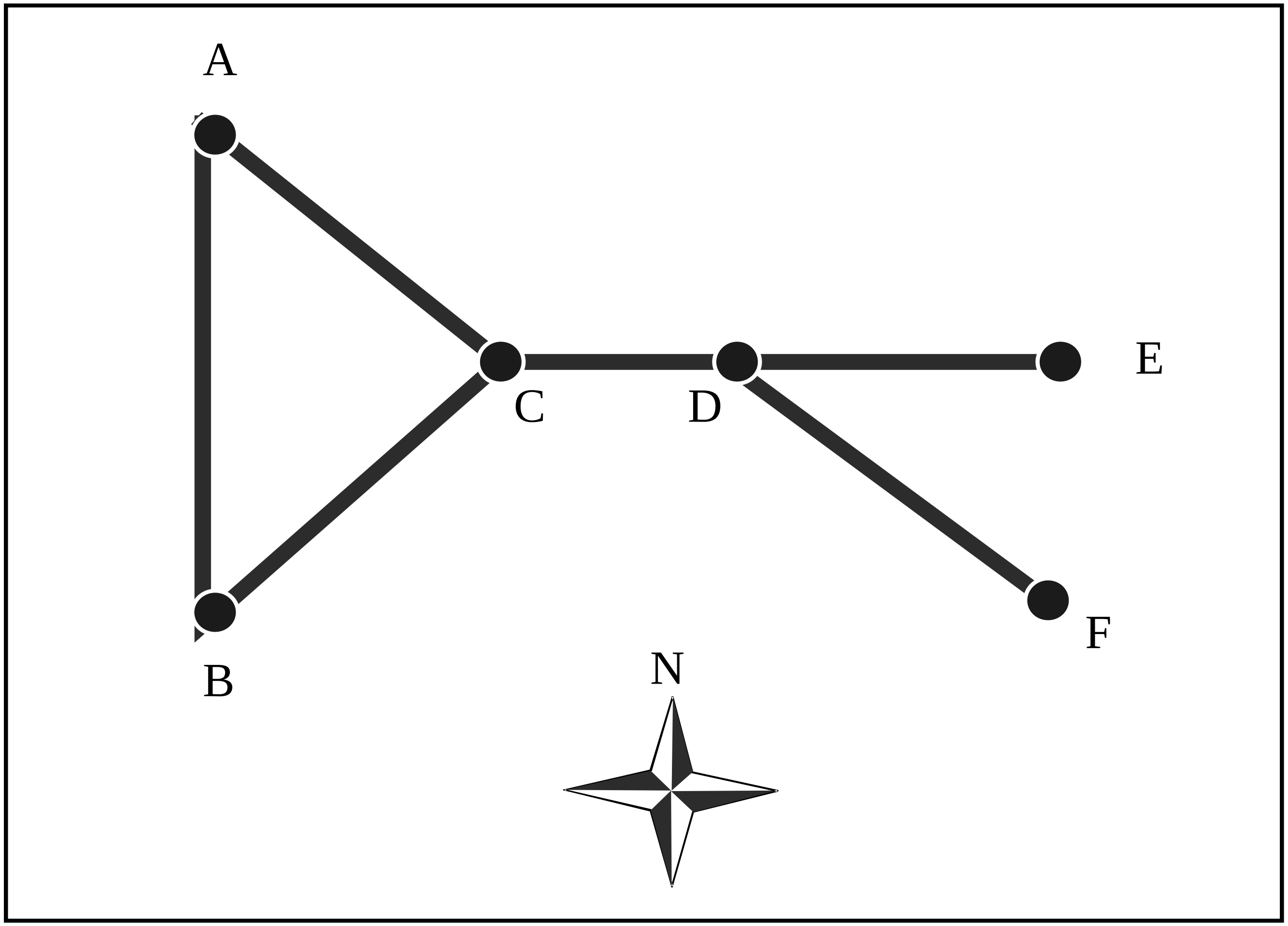
[5] In fact the consideration of *every* possible routing over *every* possible link would generate millions and millions of distinct routes. The current analysis, however, restricts the potential number of routings to include only those routes over which traffic is observed. Thus, shipments from Cincinnati to New Orleans via Omaha are generally excluded from consideration.

Figure 2.1



2.2 THE DETERMINANTS OF LINK CAPACITY

The concept of link capacity encompasses both space and time. Specifically, link capacity is measured by counting the number of output units (freight cars, revenue tons, etc.) that can be moved over the network link in a specific time period (cars-per-day, tons-per-year, etc.).[6] The actual long-run ability of a link to accommodate traffic is determined by the characteristics of the traffic that uses the link, the physical characteristics of the link, and the ability of traffic to move on to and off of the link. Within the context of railroad transport, these determinants include (but are, by no means limited to) the direction and commodity mix of traffic, the configuration and quality of line-haul trackage, and the ability of terminal facilities to yard, switch, and dispatch trains.

2.2.1 *Traffic Mix and Line-Haul Characteristics.* The traffic moving between specific origin and destination pairs is a function of the vector of available transportation rates, the availability of spatial or commodity substitutes, and ultimately, the demand for downstream goods and services. Thus, while railroads can influence origin destination flows by manipulating rates, these flows are also subject to largely exogenous forces. The same may or may not be true of actual routings. Again returning to Figure 2.1, a railroad that operates over this network may have to share control over the quantity of transportation demanded between A and F with a variety of other economic agents. It does, however, have considerable discretion over some portions of the actual routing of traffic between these points.[7] For example, if the railroad wishes to operate only westbound between C and A, A to F movements may be routed via B instead of utilizing the more direct ACDF route.

Differing traffic mixes require significantly different infrastructure configurations. Routes that handle largely one-way traffic obviously require fewer opportunities to meet opposing trains, so that sidings (passing tracks) or multiple main lines play a smaller role in determining capacity. Conversely, the capacity of routes that must accommodate two-way traffic (most routes) and particularly routes that see a

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[6] Within some contexts, the discussion may focus on the length of time it takes to move a single output unit (carload, ton, etc.) over a specific link. Analytically, these approaches are identical.

[7] In advance of deregulation, routings were determined through the use of route tariffs published by the rail carriers. In the wake of deregulation, routings may be specified in contractual agreements. Again, however, it is the individual railroads that develop the set of options from which shippers may choose. The only real opportunity for shipper control of routings comes through the process of “Accounting Rule Eleven” moves wherein a shipper treats a movement over two separate railroads as two separate shipments.

diverse mix of traffic is heavily dependent on the number and spacing of sidings and/or availability of multiple main tracks.

Apart from link configuration, the physical characteristics and quality of the trackage depends both on the volume and mix of intended traffic. Routes that serve a high percentage of fast moving intermodal traffic may require super-elevated curves, greater clearances, and enhanced track quality for higher speed operations. Routes that primarily see bulk traffic movements may be particularly sensitive to grade. Ultimately, the weight of rail used, the anchoring and ballast system selected, the type and spacing of signals, decisions regarding grading and grade separations are all impacted by the mix of traffic that the trackage must accommodate. The variety of relationships between traffic mix and infrastructure requirements is expansive. Moreover, because the mix of traffic can change significantly over time and because the reconfiguration or modification of infrastructure is both time consuming and costly, the match between traffic mix and link characteristics may be less than pristine.[8]

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[8] For example, as passenger traffic and routings declined, many railroads reduced the elevation in curves in order to reduce the rail wear associated with the operation of heavier slower-moving trains over track designed to accommodate high-speed passenger trains. However, just as many such projects were completed, the volume of intermodal shipments exploded. Intermodal trains are shorter and faster than the typical line-haul freight train, with characteristics that, in many ways, resemble passenger trains. Consequently, many carriers have found it desirable to reverse course and restore the elevated curves in some routes.

2.2.2 *Terminal Facilities*. Network nodes are formed where routes converge or diverge and where traffic can be interchanged from one network to another. In some cases these nodes and their associated functions require a minimal amount of infrastructure. At other locations, the origination, termination, interchange, and reorganization (blocking) of traffic requires acres and acres of facilities comprised of hundreds or even thousands of miles of trackage. The rate at which traffic can be passed along a network link is of little or no consequence if terminal facilities at the end of that link cannot receive the movement and dispatch it onto the next leg of its journey. Thus, terminal facilities of are of paramount importance in determining a route's capacity.[9]

This having been said, it must also be recognized that nearly every terminal facility of any size is characterized by a unique set of attributes that are the result of historical functions and relationships, topographical conditions, political bent, and sheer chance. Thus any attempt to model terminal operations is often, unproductive. Instead, any consideration of terminal congestion must be investigated on a case-by-case basis.[10]

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[9] One need only look at the UP's Houston operations or CSX's Queensgate Yard in Cincinnati to appreciate the impact that terminal congestion can have on route or even overall network capacity. Moreover, Chicago, the nation's largest rail hub, continues to produce myriad operating problems for the Class I, regional, and shortline carriers that move traffic within the region. See, "The Keys to Success," Traffic *World*, January 19, 1998, pp. 30-31.

2.2.3 *Deregulation and Railroad Mergers*. The pending transaction in which Norfolk Southern and CSX Transportation seek to acquire and divide Conrail assets represents only the latest step along a path of railroad consolidation that began after World War II. This pattern of consolidation has resulted in the movement of 70-80% of all rail traffic by only a handful of surviving Class I railroads. While shippers and policy makers continue to debate the competitive impacts of more recent mergers and acquisitions, from a functional standpoint, the pattern of rail mergers, combined with the pricing flexibility provided by deregulation has very probably led to a more efficient utilization railroad network capacity.

This potentially arguable conclusion rests on three closely related considerations. First, as the number of independent railroads is decreased, any routing flexibility retained by shippers is automatically reduced. Thus, consolidated railroads with a variety of routing options are freer to equalize traffic over

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[10] In the simplest sense, a double track main with automatic block signals operated by the Burlington Northern in Oregon may be expected to have capacity characteristics that are, at least, similar to a like piece of trackage operated by Norfolk Southern in Alabama. Thus, the cross-sectional modeling described later in this document is possible. Alternatively, no two terminals are the same, so that cross-sectional comparisons would be of virtually no value.

their expanded rail network rather than engage in the capital expenditures necessary to increase the capacity of an isolated segment of track. A second and corollary consideration is the increased ability of merged carriers to run one-way traffic on a variety of network links. Thirdly, to the extent that a carrier wishes to specialize in the movement of specific commodities over specific routes it can simultaneously adjust the configuration or quality of its network links *and* adjust prices to reflect any cost advantages that its reconfigurations in the targeted line of business.

2.3 CARRIER INCENTIVES FOR CAPACITY EXPANSION

The report that details the first phase of this ongoing research considers the matter of long-run economic incentives in some detail. There are specific circumstances in which the economic incentives facing privately held rail carriers might result in something less than the optimal amount of railroad capacity. Specifically, the presence of market externalities or a lack of effective market competition could lead carriers to constrain long-run rail capacity below socially optimal levels. While these issues may or may not reflect areas of legitimate concern, it is our judgment that their consideration within the current analysis is inappropriate.

With regard to effective competition, the traditional Corps approach assumes that all relevant markets are effectively competitive in the long-run. The implications of relaxing this assumption extend far beyond the evaluation of capacity. From a pragmatic standpoint, the competitive assumption allows observed rates to form the basis of estimated long-run costs. As importantly, the economic theory that underpins the whole of benefit calculations is equally dependent on the presence of meaningful competition. If, in fact, there are rail markets where the level of competition is insufficient to produce optimal levels of investment, then those markets should be treated through the appropriate policy prescriptions. However, when evaluating long-run railroad capacity, any necessary remedies should be presumed to be successful so that the underlying assumption of effective competition is retained.

The case of externalities provides a similar circumstance. For the most part the externalities associated with surface freight transportation stem from environmental impacts that would not routinely be captured by the transaction in which transportation services are bought and sold. In a number of instances, extant environmental policies already work to internalize these external costs, so that no further consideration is called for. In those situations where corrective environmental measures are still needed, they should be pursued. However, for the purpose at hand, it should be assumed that all necessary corrections have been (or will be) made.

SECTION 3

MODELING RAILROAD CAPACITY

3.1 LINE-HAUL VERSUS TERMINAL CAPACITY CONCERNS

The discussion in Section 2 alludes to the importance of terminal capacity as a determinant of overall route or system capacity. It is, nonetheless, our judgment that, with only a few exceptions, line-haul capacity should serve as the primary focus of the current investigation. This judgment is anchored in three observations: (1) export grain traffic that would divert to Pacific Northwest (PNW) destinations would impose little additional burden on rail terminal facilities in the Upper Mississippi region; (2) a measurable portion of the river-borne traffic considered in this study is already transported to or from the river by rail, so that much of the additional railroad tonnage already passes through affected rail terminal facilities; and (3) while diverted tonnages might represent significant increases in overall traffic for specific line-haul route segments, the magnitude of traffic diversions relative to the traffic already passing through terminals that gather and disperse rail traffic to and from numerous links is quite small. A full characterization of projected traffic diversions and their impact on regional terminal facilities is provided in Section 4 along with exceptions to the judgment proffered above.

3.2 MODELING LINE-HAUL CAPACITY

The process for estimating and assessing railroad line-haul capacity is relatively straightforward. As noted above, there are many thousands of distinct route segments that vary considerably both in quality and in utilization. It is these variations that provide the basis for statistical estimation. The whole of the process can be characterized by the following three steps:

- Identify a cross-section of railroad route segments and collect information describing the physical characteristics of those route segments including the current level of traffic.
- Functionally relate observed traffic levels to route characteristics.
- Using the estimated relationships and the vector of current input prices to estimate the costs of incremental additions to railroad capacity.

3.2.1 *Route Links and Link Characteristics.* The development of Geographic Information Systems (GIS) technologies and coverages has greatly enhanced researchers’ abilities to assemble link-specific transportation data and it is four such coverages that provide the basis for the link characteristics used in this analysis.[11] These data were, in turn, modified to incorporate information gleaned from the U.S. Federal Railroad Administration Grade Crossing Inventory files and from other sources.

Initially, a set of roughly 2,500 distinct route segments were defined for use in this analysis. As noted above, a route segment or link for a particular railroad begins and ends at any point where traffic may converge or diverge. Additionally, link end points (or nodes) occur at any location where two railroads may legally interchange traffic. Once the study links were defined, information from four GIS coverages was mapped onto these links. Data from the Bureau of Transportation Statistics' (BTS) 1995 National Transportation Atlas Data (NTAD) 1:100,000 scale railroad network were combined with a newly released Federal Railroad Administration GIS coverage to provide the basic geographic information. These data were combined with data from the BTS 1996 NTAD 1:2,000,000 scale railroad network that contains information describing signaling and a measure of traffic density. The process of developing route characteristics from GIS data is described more fully in Appendix 1. The next step in the data development process involved using a preliminary grade crossing GIS coverage developed by

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[11] Full documentation of dataset construction, including a description of GIS coverages and manipulations is available upon

Oak Ridge National Laboratories to locate the position of both separated and grade-level highway crossings. Next, data from the Federal Railroad Administration's Grade Crossing Inventory File were merged with the geographic data in order to provide additional information regarding train speeds, train frequencies and other operating characteristics.

The geographic units, referred to as arcs, are between a few tenths of a mile to several miles in length. However, the shortest route or study segment length is measured in miles and some route segments are several hundred miles in length. Consequently, each route segment generally consists of many arcs. It was, therefore, necessary to aggregate arc level data to conform to the route level unit of measure. This process is depicted in Figure 3.1. Missing data on some route segments precluded their use in any statistical application. Therefore, the final data set contains roughly 1,400 observations or route segments. The location and extent of their coverage is displayed in Figure 3.2. A full definition of all route level data used within the final model estimation analysis is contained in Table 3.1.

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request.

Figure 3.1

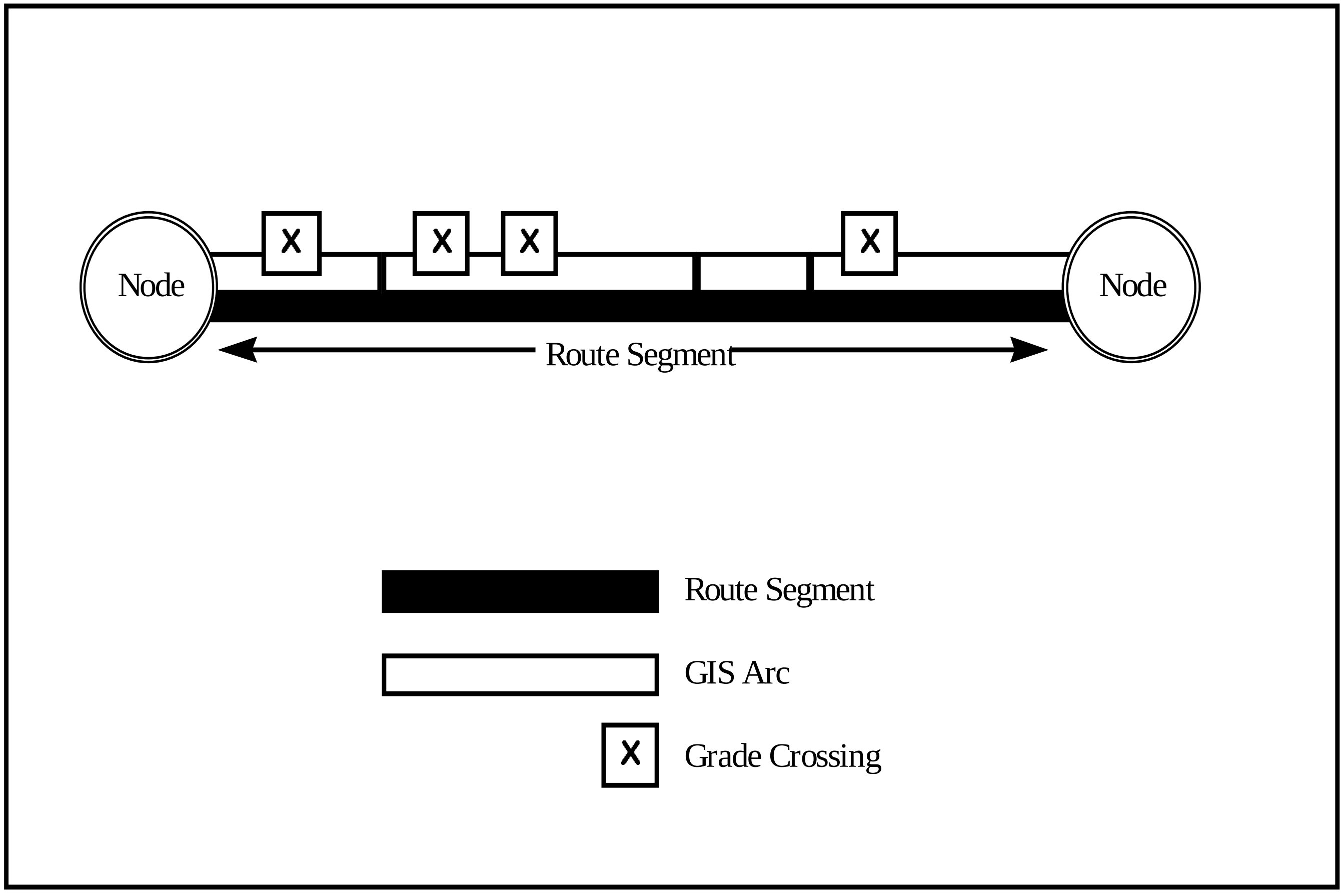
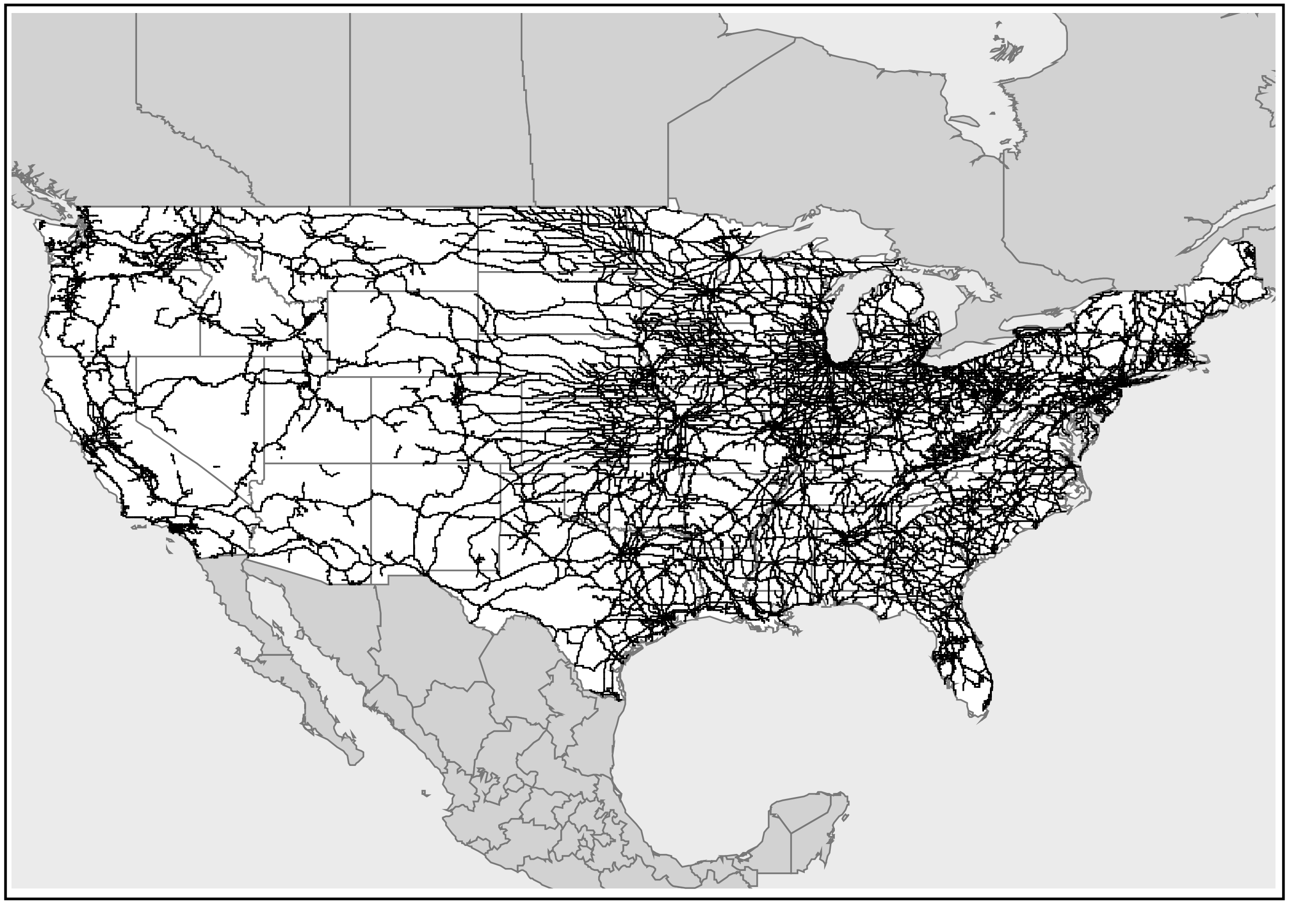

Node
Node
Route Segment
Route Segment
GIS Arc
Grade Crossing

Figure 3.2



3.2.2 Measuring Observed Traffic. At the center of this analysis is a fundamental assumption that the components of the rail network, as configured in 1994-95, were optimally suited to accommodate the traffic moved during that period. Thus, the traffic observed on each link during the study period stands as a measure of that link's capacity.

To measure the traffic over each link, the expanded movements from the Surface Transportation Board's annual Carload Waybill Sample were routed over the 1997 FRA 1:100,000 GIS network. A full description of the routing process is available in Appendix 2. However, several points are worth noting here. First, routings were based on actual origin, destination, participating carriers, and recorded points of interchange. Beyond these criteria, routes were selected on the basis of the shortest distance. This "short-line" criterion generally reflects railroad operating practices. This is not, however, true in every case. In order to assess the validity of the algorithm used in the routing process, model outputs for 89 of the 100 hundred most heavily used routes were compared with routings generated by an alternative method.[12] In 80 of the 89 cases, the TVA algorithm generated routes that were virtually identical to the paths generated with the alternative software. In 8 cases, there were significant variations reflecting cases in which railroads opt for a more circuitous routing and in one case, the TVA route varied from the actual routing because of a line sale. The sample of 100 was fully corrected and, because this sample represents between 15% and 20% of all rail traffic, we have complete confidence in a significant portion of the data. Moreover, the remaining rate of error appears to be within acceptable parameters. Once the CWS records were routed over the rail network, tonnage and car loadings were summed at the route link level to form measures of relative capacity

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[12] The 1995 CWS contains nearly 500,000 records that reflect more than 75,000 routings. Except as noted in the GIS documentation, each of the geographic path of each of these unique routes was calculated for use in this analysis. The comparison routes were developed through the use of PC Rail, a software product produced by ALK Associates in Princeton, New Jersey.

3.2.3 *Model Specification*. As discussed in Section 2, line-haul link capacity is a function of track configuration and the quality of track components, as well as exogenous factors including, but limited to topography (grade) and weather conditions. A number of model specification and functional forms were discussed with Corps personnel, independent transportation consultants, and other industry experts. Ultimately, the following model was selected.

$$\begin{aligned}\text{MAXCARM}_i = \beta_0 \quad + \quad & \beta_1(\text{TIMETBLS}_i) + \beta_2(\text{CTCSPEED}_i) + \beta_3(\text{SPEEDRAT}_i) + \\ & \beta_4(\text{TRAINLEN}_i) + \beta_5(\text{MAINS}_i) + \beta_6(\text{CTCMAIN}_i) + \beta_7(\text{SIDSIZ}_i) + \beta_8(\text{SIDINGS}_i) + \\ & \beta_9(\text{SIDINT}_i) + \beta_{10}(\text{ABS}_i) + \beta_{11}(\text{CTC}_i) + \beta_{12}(\text{SWITCH}_i) + \beta_{13}(\text{SWITCH2}_i) + \\ & \beta_{14}(\text{ROUTLEN}_i) + \\ & \beta_{15}(\text{ROUTLN2}_i) + \\ & \qquad \sum \gamma(\text{CD}_i) + \varepsilon_i\end{aligned}$$

Variable definitions are provided in Table 3.1

Table 3.1

Variable	*Description*
MAXCARM	The dependent variable is defined as the natural log of the number of gross carloads accommodated by the ith route link in the busiest 1995 calendar quarter. The log-linear specification was adopted to help capture any non-linear relationships between the dependent variable and explanatory variables. Gross carloads reflect the sum of revenue carloads and estimated empties.[13] The maximum quarterly value was selected to reflect seasonal variations in traffic levels and the assumption that infrastructure is constructed to accommodate the seasonal peak load.
TIMETBLS	Average timetable speed along the route link in question calculated by averaging the reported timetable speed at highway grade crossings. This variable is included as a measure of track component quality.[14]
CTCSPEED	The product of TIMETBLS and CTC, a measure of centralized traffic control described below. This interaction term is included to capture substitutability / complementarities between signal quality and track component quality [15]
SPEEDRAT	The ratio of the minimum train operating speed to the timetable speed included capturing variations in train speeds.

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[13] Empty return ratios (ERRs) were based on a similar parameter used in cost calculations within the Rebee Rail Costing Model. Gross carloads equal (revenue carloads) x (1+ERR).

[14] As with most such analyses, there are innumerable data problems. In the case of timetable speed, the data reflect freight train speeds where no passenger service is operated, but reflect timetable passenger train speeds where passenger trains are present.

[15] For example the effect of timetable speed is reflected by the partial derivative of the model equation with respect to TIMETBLS. Normally, this would simply be the estimated coefficient for TIMETBLS, but because of the interaction term, the derivative includes is:

$$\frac{\partial \text{ MAXCARM}}{\partial \text{ TIMETBLS}} = \beta_1 + \beta_2(\text{CTC})$$

Variable	*Description*
TRAINLEN	The average train length observed along the network link calculated as the gross number of carloads divided by the total number of daily trains.
MAINS	The estimated proportion of mainline tracks within the route estimated by combing the number of mainline tracks at grade crossings throughout the link in question and the carrier-specific ratio of additional mainline miles to total route miles operated.
CTCMAIN	The product of CTC and MAINTRAK. This term is included to reflect substitutability or complementarity between signal quality and the amount of mainline trackage.
SIDSIZ	The average siding length along the route segment.
SIDINGS	Estimated proportion of sidings to mainline trackage based on the carrier specific ratio of sidings to mainline trackage and the number of “other” tracks observed at highway grade crossings along the specific route.
ABS	The percentage of the route link that is controlled by automatic block signals (ABS). ABS is assumed to be inferior to centralized traffic control (CTC), but superior to unsignaled or “dark” territory.
CTC	The percentage of the route link that is controlled by centralized traffic control (CTC).
SWITCH	The average number of daily switch movements along the link in question.
ROUTLEN	The route length as calculated from the GIS coverage. Because individual arcs were missing from some links, there are numerous instances in which the calculated route length is less than the actual length. This should not, however, affect the validity of the estimation results. To capture in additional non-linearities a quadratic term ROUTLEN2 is included in the specified model.
CD	Carrier intercept terms.[16]

3.3 ESTIMATION RESULTS

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[16] A fully interactive model that included interactions between the carrier intercept terms and the other independent variables was tested, but rejected, as it offered no measurable improvement.

A full set of estimation results is provided in Table 3.2. On the whole, these results support the hypothesized link-specific correlation between observed rail traffic and those variables used to represent the quality and configuration of track structures. We must also conclude, however, that the general degree of model fit and the weak statistical significance of some variables suggests that factors other than track quality and configuration are also important determinants of the level of traffic observed on a particular route segment.

Based on the estimates, the greater train speeds that are facilitated by better track components appear to significantly improve the carload capacity of a network link, while variations in train speed reduce capacity. The coefficient estimates for CTC and ABS clearly indicate that the quality of signaling affects capacity and, as anticipated, the magnitude of CTC is considerably greater than that of ABS. Track capacity is negatively correlated with train length, indicating that, all else equal, it is more difficult to meet and manage trains of greater length. Coefficient estimates for the two interaction terms, CTCSPEED and CTCMAIN, were both negative and statistically significant. Moreover, their magnitudes, relative to

Table 3.2

Variable	*Coefficient Estimate*	*Standard Error*	*"t" (Parm=0)*	*Probability Parm=0*
INTERCEPT	8.289905	0.277913	29.829	0.0001
TIMETBLS	0.033229	0.002437	13.635	0.0001
CTCSPEED	-0.017	0.00365	-4.657	0.0001
SPEEDRAT	0.178289	0.09967	1.789	0.0739
TRAINLEN	-0.00091	6.66E-05	-13.614	0.0001
MAINS	0.7272	0.090022	8.078	0.0001
CTCMAIN	-0.41692	0.131276	-3.176	0.0015
SIDINGS	0.948858	2.394492	0.396	0.692
SIDSIZ	0.095958	0.024872	3.858	0.0001
ABS	0.430842	0.066326	6.496	0.0001
CTC	1.854777	0.177132	10.471	0.0001
SWITCH	0.113847	0.019442	5.856	0.0001
SWITCH2	-0.00517	0.001686	-3.064	0.0022
ROUTLEN	-0.00088	0.001075	-0.815	0.4155
ROUTLEN2	3.46E-06	5.17E-06	0.669	0.5036
CD076	CONFIDENTIAL[17]			
CD190				
CD712				
CD400				
CD555				
CD482				
CD721				
CD802				
Adjusted Model $R^2 = 0.6012$				

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[17] Because confidential Waybill records were used to develop traffic volumes, carrier-specific estimation results are also held to be confidential.

estimates for the independent variables from which they are formed, supports the hypothesis that improved signaling increases capacity more when there are fewer mainline tracks or when train speeds are lower, but is a less effective means of adding capacity when multiple main tracks are present or when train speeds are already at relative high levels.[18] The coefficient estimates for SIDSIZ, and SIDINGS display the anticipated signs, although the magnitude and statistical significance of these estimates would, at first glance, appear to under-represent the importance of sidings as a means of adding link capacity.

3.4 INTERPRETING THE RESULTS

The estimation results as depicted in Table 3.2 are useful in evaluating the overall model performance. However, from the standpoint of assessing track capacity, a series of result applications may be more useful. Tables 3.3-5 illustrate the estimated relationship between independent variables and track capacity as measured by observed traffic under three different circumstances.

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[18] While the interaction terms work to offset the individual coefficient estimates, the effects of additional mainline trackage or CTC are still positive. In every case the sum of the interaction terms and independent variables was statistically different from zero at a 95% level of confidence.

Table 3.3 illustrates the estimated track capacity for a 100 mile route segment of minimal quality. It is unsignaled, without sidings or additional main tracks, and suitable for train speeds of 20 m.p.h. or less. The estimation results suggest that trackage with this configuration and quality would support roughly five 40 car trains each day.[19] Based on consultation with industry experts, this estimated capacity appears reasonable.

Table 3.3

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	20	SIDSIZ	0
CTCSPEED	0	ABS	0
SPEEDRAT	1	CTC	0
TRAINLEN	40	SWITCH	0
MAINS	1	SWITCH2	0
CTCMAIN	0	ROUTLEN	100
SIDINGS	0	ROUTLEN2	10000
Estimated Capacity	17,514		
	5	Trains Per Day	

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[19] Exponentiation of the intercept term reported in Table 3.5 suggests that nearly every piece of trackage, under any configuration and in any condition, will support one train a day.

Table 3.4 depicts the estimated capacity for a route segment based on the mean values of the independent variables. These data, therefore, depict an “average” route segment based on the sample of roughly 1,300 such segments. As would be expected this typical track segment reflects both better component quality and a more complex configuration. Consequently, it is estimated to accommodate nearly twice the number of daily trains and nearly four times as many cars as the trackage of minimal quality and configuration. Nonetheless, these results do reveal evidence that the data may not be entirely effective at measuring the intended variables. In particular the mean values for SIDINGS and SIDSIZ highlight the lack of specificity that is likely responsible for the rather lose model fit. It is impossible to discern whether these data reflect 14 equally sized (and very small) sidings or a much smaller number of more usable sidings.

Finally, Table 3.5 depicts a piece of trackage that is clearly superior to the sample mean. The route in this example is fully signaled with CTC, can accommodate 69 m.p.h. train speeds, and features a significant amount of secondary main, as well as a copious volume of passing track. This trackage is estimated to accommodate more than four times the number of daily trains and train cars hosted by the “average” track depicted in Table 3.7. Still, consultants, familiar with the industry, have suggested that the trackage portrayed in Table 3.8 would, in fact, be able to accommodate a volume of traffic that significantly exceed the estimated 40 trains per day. Generally, it is our assessment that the estimation results systematically understate link capacity for higher quality route segments.

Table 3.4

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	38	SIDSIZ	0.321
CTCSPEED	14.858	ABS	0.161
SPEEDRAT	0.4848	CTC	0.391
TRAINLEN	79	SWITCH	1.970
MAINS	1.158	SWITCH2	3.881
CTCMAIN	0.452	ROUTLEN	41
SIDINGS	0.108	ROUTLEN2	1681
Estimated Capacity	64,226		
	9	Trains Per Day	

Table 3.5

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	69	SIDSIZ	5
CTCSPEED	69	ABS	0
SPEEDRAT	1	CTC	1
TRAINLEN	65	SWITCH	0
MAINS	1.2	SWITCH2	0
CTCMAIN	1.2	ROUTLEN	100
SIDINGS	0.2	ROUTLEN2	10000
Estimated Capacity	236,368		
	40	Trains Per Day	

SECTION 4

RAILROAD CAPACITY FOR UPPER MISSISSIPPI BASIN SHIPMENTS

The ultimate purpose of this research is to evaluate the extent to which diverted Mississippi River traffic would affect the need for and cost of railroad capacity for movements to, from, and within the Upper Mississippi basin. Armed with the estimation results developed in Section 3, predictions of diverted traffic, and rule-of-thumb measures of incremental track component and configuration costs, this section seeks to finally address the central focus of this study.

4.1 CAPACITY COSTS

The cost of building or modifying line-haul railroad trackage is, of course, a function of the quality and configuration of that trackage. It is also, however, affected by a wide array of exogenous factors. Specifically, soil conditions, terrain, environmental concerns, and the degree of urbanization can all significantly impact the cost of a particular construction project. The challenge, within the current context, is to mitigate the effects of these specific factors in order to develop generic cost estimates that can be reasonably applied to a variety of potential infrastructure improvements.

Table 4.1 provides a summary of the generic or "rule of thumb" measures for costing the construction or modification of rail infrastructure developed by civil engineers the University of Tennessee's Transportation Center. Appendix 3 fully documents the methodology, data, and calculations used to produce these estimates. It should be noted, as well, that preliminary estimates were discussed with engineering professionals from a number of Class I railroads and with experts from private construction firms that are routinely engaged in rail project construction. It is, of course, possible to point to innumerable examples of rail infrastructure projects where the actual incurred costs are quite different than those contained within Table 4.1. We are, however, extremely confidant that the UT estimates are both reasonable and reliable.

Table 4.1 also contains the estimated necessary real rate of return on capital investments. Varying this rate, even modestly, has a significant impact on the final costs of multi-million dollar projects that span several decades. It is, therefore, important to carefully select this rate. To simplify the estimation, the analysis ignores the potential impact of expected inflation, focussing instead on the *real* necessary rate of return. It is also important that the identified rate reflect the necessary return under conditions of competitive supply. Any observed impacts that result from the exercise of market power must be eliminated. The necessary rate of return should, instead, be a forward-looking, long-run, least-cost estimate of the cost of capital. Ultimately, after numerous machinations in consultation with a variety of sources, the current analysis settled on a real necessary rate of return of 8%. This figure, in combination with recent price patterns, yields nominal rates of return that are somewhat less than the benchmark rate established by the Surface Transportation Board for the assessment of revenue adequacy, but greater than the historical rates of return for most Class I carriers.

Returning to the expense of actually constructing or modifying trackage, the analysis assumes that siding construction varies from main-line construction both in the quality of track components and in their placement. For example, the calculation of siding costs incorporates the use of re-lay (used) rail. It also is based on tie spacing that is greater than those used to support mainline track. Light density trackage is of the construction typically found on long industrial tracks, small branch-lines, or

Table 4.1

Base Case				
Summary	Track $/Mile	Track $/Ft	Turnout cost	Control point cost
Siding Case	$383,730	$73	$98,768	$129,290
Light density case	$411,231	$78	333$92,768	$129,290
Medium density case	$457,013	$87	$98,768	$129,290
Heavy haul case	$489,841	$93	$119,691	$129,290
Variations in Terrain				
	Existing ROW	New ROW		
	Incr. $/Mile	$/Mile		
Flat Terrain		$119,262		
Rolling Terrain	$163,612	$786,241		
Mountainous Terrain	$546,532	$3,795,915		
Isolated Signal Projects[20]				
Signal Upgrades	$605,000			
Finance Costs				
Rate of Return	8%			

Class III railroad mainlines. This track classification is designed to handle modest tonnages at moderate speeds. The medium density case provides cost calculations for the type of trackage typically found on

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[20] The University of Tennessee output did not specifically include isolated signal project costs. It did, however, contain data detailing the actual costs associated with a handful of such projects. TVA to develop the cost estimate used within the analysis used these figures.

Class I mainlines. This track will support moderate to heavy traffic at track speeds up to perhaps 60 m.p.h. Finally, the heavy haul case reflects the costs of constructing state-of-the-art trackage capable of handling continuously moving heavy traffic as might be evidenced in the Powder River region or within the northeast corridor. Here, rail weight is assumed to be, at least, 136 lbs., concrete ties are placed along with advanced anchoring systems, and ballast (and sub-ballast) levels are at their greatest.

The application of the UT cost estimates is reasonably straight forward. For example the construction of a one-mile long siding on existing right-of-way over flat terrain would include $383,730 for actual track construction, two turnouts at $98,768 each, and two control points (If CTC) at a cost of $129,290 per location for a total cost of $839,846. A signal upgrade from ABS to CTC over five miles of trackage would cost 5 X $605,000 or $3,025,000. Finally, the new construction of a 10 mile long second medium-haul main track through hilly terrain would cost $12,712,366 for earth work, track installation, turn-outs, control points and signals.

4.2 TRAFFIC DIVERSIONS AND ALTERNATIVE TRAFFIC FLOWS

The actual policy issue inherent in the Upper Mississippi basin is not so much whether extant river traffic will be lost to alternative modes, it is whether the projected growth in traffic will increase lock delays, thereby, increasing the costs incurred by current barge shippers and driving the preponderance of the increased traffic onto the railroads or highways, thereby altering the future costs of transport for railroads or highways. Thus, the phrase “diversion” is a bit misleading. Nonetheless, given that traffic growth on the Upper Mississippi River is forecast to be roughly 100%, a simple way to estimate the order of magnitude of this growth and its potential impact on other modes is to divert the entirety of current river traffic onto the existing highway and rail systems.

Table 4.2 contains a summary of projected traffic diversions for all non-crop commodities to alternative routings (either entirely by land or via a land/barge combination over the Port of St. Louis).[21]

For grain movements, it is again assumed that barge rates escalate to the point that navigation on the upper reaches of the Mississippi no longer provides a competitive transportation alternative. However, unlike non-grain commodities, a number of additional potential diversions are considered.

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[21] These traffic diversions are developed specifically for application within the current analysis and may differ from the final

Table 4.2

Commodity	*Diversions to an All-Land Alternatives (in Tons)*	*Diversions to a Rail-Barge Alternatives Over St. Louis (in Tons)*
Coal	21,774,645	808,033
Petroleum Products	11,588,400	2,380,167
Chemicals	3,391,702	1,375,243
Fertilizers	4,233,323	989,819
WWIM, Ores, I&S Scrap, Slag	7,606,548	1,753,492
Stone, Sand, Cement	15,682,225	3,249,310
Processed Products	4,486,545	2,627,181
TOTAL	68,763,387	13,183,246

First, grain that is currently flowing over Louisiana Gulf destinations selects between an all rail routing to either a Louisiana or Texas export destinations or a rail/barge combination to a suitable Louisiana Gulf destination. Additionally, it is possible for export grain to divert to the Pacific Northwest (PNW). The actual diversion is based on the transportation rates developed within the NED analysis. Data describing these alternative flows are contained in Table 4.3. The quantities of traffic are projected graphically in

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traffic diversions estimated within the traditional NED analysis.

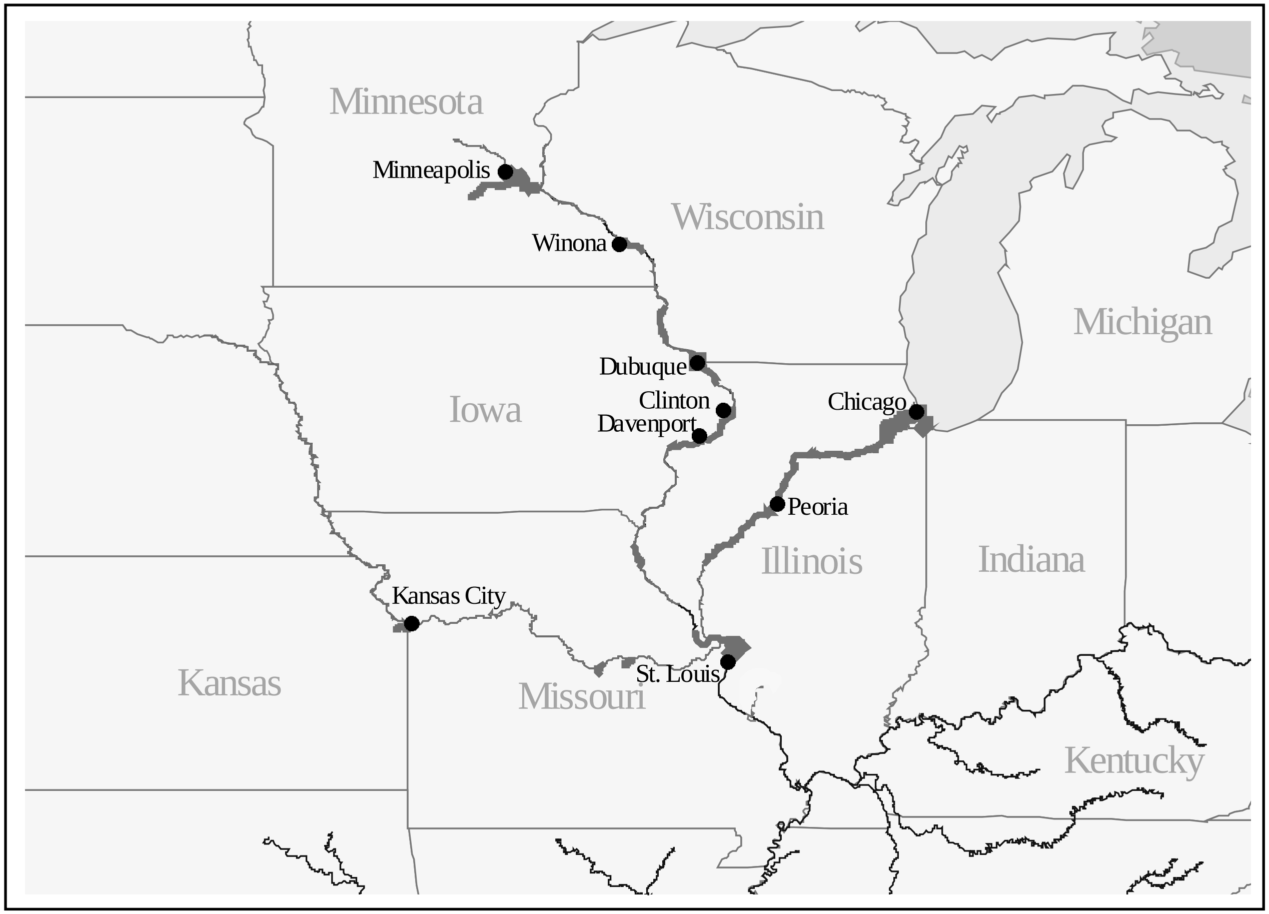
Figure 4.1 where the width of the origin or destination pool reflects originating or terminating tonnages. A graphical representations of total inbound and outbound commodity flows is provided in Figure 4.1.

Table 4.3

Commodity	*Diversions to All-Land Alternatives (in Tons)*	*Diversions to a Rail-Barge Alternatives Over St. Louis (in Tons)*	*Diversions to Texas Gulf Alternatives (in Tons)*	*Diversions to the Pacific Northwest (in Tons)*
Corn	11,086,635	21,405,515	197,896	17,424
Soybeans	4,827,659	7,571,023	67,962	5,984
Wheat	2,741,581	2,409,297	279,104	440,256
Barley, Oats, and Sorghum	432,551	432,551	432,551	432,551
Total	19,088,426	31,818,386	977,514	896,215

Roughly one million tons of grain from western Iowa, western Minnesota and northeastern Nebraska would divert to the PNW and a similar amount of grain from southwestern Nebraska and eastern Kansas would move directly to Texas Gulf export locations. With these two exceptions, however, the vast majority of all commodity flows would remain in the Mississippi Valley. Moreover, given the amount of traffic that would rejoin the navigation system at St. Louis, it seems reasonably clear that it is railroad capacity to and from (as well as, within) St. Louis that is most critical to the efficient diversion of Upper Mississippi traffic.

Figure 4.1


Minnesota
Minneapolis
Winona
Wisconsin
Michigan
Dubuque
Clinton
Davenport
Iowa
Chicago
Peoria
Illinois
Indiana
Kansas City
St. Louis
Kansas
Missouri
Kentucky

In the above figure the width of the various navigation pools reflects the relative activity as measure by 1995 originating and terminating tonnage.

4.3 LINE-HAUL CAPACITY AND CAPACITY COSTS

Given the above discussion, our examination of line-haul capacity costs is focused on the railroad route segments that connect the Upper Mississippi Valley with the St. Louis gateway. In the event that inland navigation cannot help to accommodate increased traffic, these rail route segments would be required to process considerably more traffic than they are currently configured to handle. Using the data developed thus far, we now turn to the task of estimating the cost remedying this capacity shortfall.

Ideally, it would be possible to divert every affected shipment onto the specific route predicted by current economics in order to precisely gage the incremental capacity necessary on every route-mile of track. However, both temporal and funding constraints preclude the possibility of such an analysis. Moreover, as recognized above, railroads now have more latitude than ever over actual routings, so that even the slightest future cost perturbation could make the currently predicted routings marginally inaccurate. As a second best approach, we elected to focus on a sample of 15 route segments that, together, comprise roughly 750 miles of the 5,000 miles of mainline trackage that connects the study region to the St. Louis area. These route segments and their characteristics are summarized in Table 4.4 below. The confidentiality of the waybill records used to develop carload estimates precludes the specific identification of these routes. However, these segments reflect trackage in Illinois, Iowa, Missouri, and

Wisconsin and represent properties operated by Burlington Northern - Santa Fe, Union Pacific (traditional), Union Pacific (C&NW), Norfolk-Southern and the Soo Line. Finally, without specific knowledge of the necessary incremental capacity, we proceed through the remainder of this analysis guided by the base-line goal of doubling currently observed capacity.

Appendix 4 contains incremental capacity cost calculations for each of the route segments depicted in Table 4.4. The similarities and contrasts revealed through a comparison of these calculations are very informative. First, it is clear that the circumstance in which it is easiest to increase capacity is one where the track in question is of modest construction, poorly maintained or otherwise configured in a way so as to provide only nominal current capacity. For example, consider the route segment identified as No. 12 in Table 4.4. Here, the average timetable train speed is only 16 m.p.h. and the ratio of minimum to timetable speed indicates that a number of trains operate at speeds well below the timetable average. At the same time, the presence of CTC suggests that this was once a route segment intended to accommodate a significant amount of trackage. In an attempt to increase the capacity of this route, we elected to completely overhaul it by installing entirely new medium capacity trackage on the existing right

Table 4.4

Route	*Timetable Speed*	*Minimum / Timetable Speed Ratio*	*Train Length (cars)*	*Number of Mainline Tracks*	*Proportion of Sidings*	*Siding Size*	*Proportion of ABS*	*Proportion of CTC*	*Daily Switch Movements*	*Route Length (miles)*	*Carloads Per Quarter*
1	17	0.26667	64	1.63	0.0991		0.6667	0.3333	0.00	10	47,019
2	64	0.00347	10	1.54	0.0991		0.9412	0.0588	0.00	81	170,826
3	44	1.00000	44	1.23	0.0991	0.210	0.0000	1.0000	0.00	18	101,688
4	33	0.44321	44	1.01	0.0991		0.0000	0.0000	0.06	112	29,199
5	46	0.03111	30	1.74	0.0991	1.613	0.9750	0.0250	2.91	112	165,761
6	59	0.55682	31	2.03	0.1113		0.0000	0.0000	0.00	25	143,544
7	32	0.38450	391	0.87	0.1113		1.0000	0.0000	0.02	33	27,775
8	29	0.31925	9	1.16	0.1113		0.0000	0.0000	0.92	31	30,638
9	29	0.24576	59	1.05	0.1113		0.0000	0.0000	0.28	40	24,258
10	45	0.49551	65	1.42	0.1113		0.0000	0.0000	1.74	8	67,010
11	27	0.34560	18	0.92	0.1280	0.390	0.0000	0.0000	0.97	46	20,197
12	16	0.25597	48	0.38	0.0771	2.920	0.0000	0.8000	2.12	29	39,628
13	19	0.21621	141	0.88	0.0771	0.600	0.0000	0.0000	2.20	91	14,379
14	54	0.62957	23	1.20	0.1241	0.410	0.0000	1.0000	2.78	58	161,393
15	40	0.52895	144	0.96	0.1241		0.0000	1.0000	0.26	79	78,151
Mean	37	0.38151	75	1.20	0.1055	1.024	0.2389	0.2811	0.95	52	54,555

of way, adding two, 10,000 foot sidings, and completing the CTC over the entirety of the route. The costs of these measures would be significant - nearly $22 million in total. However, these expenditures also would purchase a significant increase in annual capacity. Absent the rehabilitation, in its current condition, the route segment can accommodate roughly 160,000 car movements per year. After the track replacement, signal improvements, and siding construction described above, the same route segment is estimated to accommodate more than 375,000 car movements per year. Even assuming a 100% empty return ratio (ERR), the rehabilitated route segment could be used provide over 300 million ton-miles of transportation services. If we assume that, on average, the components of this upgrade will have a productive life of 30 years, then the cost of the incremental track capacity is estimated to be 0.64 cents per ton-mile. A route description and incremental calculations are provided in Table 4.5.

While the calculations described above are all that is necessary to facilitate the comparison of incremental rail costs and incremental barge costs, they do not answer the concerns of most shippers. From the standpoint of shippers, the 0.64 cents per ton-mile incremental capacity cost is only relevant when viewed in comparison to the capacity costs currently embedded in observed railroad rates. If the incremental cost exceeds current capacity costs, the future average will increase; so that cost-based rates would also be forced to increase. Alternatively, if the incremental cost of the capacity necessary to accommodate increased demand is less than the capacity costs currently embodied within rates, then the future average capacity cost would be lowered and competitively determined rates would decline. While a formal comparison of these costs is beyond the scope of the current research, an arms' length

Table 4.5

Route and Route Characteristics	
State of Operation	Illinois / Iowa
Average Timetable Speed	16.28
Siding Size	2.92
Percent ABS	0
Percent CTC	0.8
Route Length	28.88
Daily Switch Movements	2.11829
Average Train Length	48.119
Train Speed Ratio (Minimum / Timetable	0.25597
Number of Mainline Tracks	0.38129
Proportion of Trackage with Sidings	0.07711
Carloads Per-Year Supported	158,512
Infrastructure Improvement and Costs	
Rebuild Track to Medium Density Standards	17,923,650
Install (2) 10,000’ Sidings	1,855,072
Upgrade Remaining Track Signals to CTC	3,978,480
Finance Cost	$35,953,496
TOTAL	57,855,626
Incremental Capacity Improvement	
In Carloads Per-Year	218,514
Percentage of Original	237.85%
In Ton-Miles (100% ERR)	302,912,747
Incremental Per-Ton-Mile Capacity Cost	$0.00637

examination suggests that the incremental cost of additional capacity along this route is unlikely to adversely affect competitively determined rates. Using 4.5 cents per ton-mile as a ball-park rate, traditional rail costing models would assume that roughly two-thirds of this rate is attributable to variable costs, while the remaining 1.5 cents per ton-mile is a necessary contribution toward fixed costs.[22] Determining the precise proportion of that penny and one-half that accounts for the historical cost of line-haul capacity would constitute and arduous (and very probably contentious) accounting exercise. Nevertheless, the 0.64 cents incremental capacity cost does not, at a glance, appear to threaten markedly higher railroad rates.[23]

It is one thing to indicate that a poorly constructed or maintained piece of trackage could be rehabilitated to provide cost-effective new capacity, but what of those cases where the infrastructure is already of a high caliber?   The route numbered 14 in Table 4.4 provides an ideal opportunity to examine

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[22] While 4.5 cents per ton-mile reflects a men rate across all commodities in all markets, it is not uncommon to observe grain rates that are as low as 1.8 cents per ton-mile or rates for the movement of coal that are in the range of 1.2 cents. Thus, even considering that variable costs for unit train movements of dry bulk commodities are lower than for other movements, it is still apparent that the current methodology provides only a rough approximation of the fixed cost of providing line-haul trackage.

[23] It is important to recall that the Corps' Principles and Guidelines call for the assumption of adequate capacity unless there is compelling evidence to the contrary.

the incremental capacity costs associated with expanding the capacity of an already well functioning rail route. In contrast to the first example, average timetable train speeds are at nearly 55 m.p.h. and the variability of observed train speeds is considerably lower. The route is already fully signaled with CTC and there would seem to be few options for increasing route capacity. This route segment typifies the upper end of the medium-haul case described in the UT cost calculations.

The calculations detailed in Table 4.5 reflect our attempt to transform this route segment into a premium heavy-haul line. Existing trackage is supplemented with the addition of a second 58 mile mainline constructed to heavy-haul standards and two additional 10,000 foot sidings. Additionally, it is assumed that 25% of the new second main must be constructed on newly acquired right of way, so that the per-mile construction cost escalates to $809,110 per mile.[24] The total cost of this rehabilitation is in excess of $145 million. However, as Table 4.5 indicates the incremental increase in line-haul capacity is estimated to be more than one billion ton-miles per year. Again, assuming a thirty year asset life, the cost of this incremental capacity is estimated to be 0.43 cents per ton-mile, or somewhat less than the incremental cost in the first example.

Table 4.5

Route Characteristics	
State of Operation	Missouri
Average Timetable Speed	54.35
Siding Size	0.41
Percent ABS	0
Percent CTC	1
Route Length	58.472
Daily Switch Movements	2.11829
Average Train Length	23.092
Train Speed Ratio (Minimum / Timetable	0.62957
Number of Mainline Tracks	1.2021
Proportion of Trackage with Sidings	0.12409
Carloads Per-Year Supported	524,729
Infrastructure Improvements And Costs	
Construct 2nd Main Track to Heavy-Haul Standards	$53,099,008
Install (2) 10,000' Sidings	$1,855,072
Finance Costs	$90,210,006
TOTAL	$145,164,085
Incremental Capacity Improvement	
In Carloads Per-Year	397,928
Percentage of Original	175.83%
In Ton-Miles (100% ERR)	1,116,847,116
Incremental Per-Ton-Mile Capacity Cost	0.0043

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[24] As with virtually all examples developed in this investigation, it is assumed that the terrain is rolling rather than flat or

Table 4.6 summarizes the incremental cost calculations for each of the 15 sample route segments. On average, under a variety of different scenarios, involving many different carriers, in at least four Upper Mississippi basin states, the incremental cost of an additional ton-mile of line-haul capacity is estimated to be 0.395 cents. These estimates clearly indicate that if necessary, Class I rail carriers can add the appropriate volume of new line-haul capacity at a cost, which is very unlikely to prove harmful to the overall level of competitively, determined rail rates.

4.4 TERMINAL CAPACITY

A diversion of Upper Mississippi river traffic to the rail network would increase traffic levels in a number of terminals throughout the region. Specifically, the Twin Cities, Chicago, Omaha/Council Bluffs, Lincoln, Kansas City, and Houston would all see additional rail traffic. At these locations, however, the incremental increase in rail traffic could be measured in carloads per-day. Consequently, an exhaustive study of whether or not sufficient capacity exists seems unwarranted. By comparison, rail traffic within the St. Louis area would increase precipitously both because of the additional traffic that

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mountainous. Refer to Appendix 3 for a description of these terrain conditions.

Table 4.6

Example Number	*Carloads Per-Year Supported (x 1,000)*	*Infrastructure Improvement Cost (x 1,000)*	*Finance Costs (x1,000)*	*Total Incremental Capacity Cost (x 1,000)*	*Incremental Capacity Carloads Per-Year (x 1,000)*	*Percentage of Original*	*In Ton-Miles (100% ERR), (x 1,000)*	*Incremental Per-Ton-Mile Capacity Cost*
1	188	$1,803	$2,960	$4,763	116	161.53%	28,216	$0.00563
2	683	$22,869	$37,541	$60,410	254	137.10%	491,722	$0.00410
3	407	$8,649	$14,198	$22,848	110	127.04%	47,693	$0.01597
4	117	$67,808	$111,475	$179,284	277	337.22%	745,236	$0.00802
5	663	$18,017	$29,576	$47,592	139	120.99%	373,852	$0.00424
6	574	$15,246	$25,027	$40,273	309	153.86%	187,016	$0.00718
7	111	$21,548	$35,224	$56,772	95	185.54%	148,471	$0.01275
8	123	$20,489	$33,634	$54,123	209	270.23%	308,423	$0.00585
9	97	$26,880	$44,125	$71,004	186	291.23%	354,738	$0.00667
10	268	$1,053	$1,729	$2,782	177	165.88%	70,857	$0.00131
11	81	$30,897	$50,719	$81,616	170	311.04%	380,282	$0.00715
12	159	$21,902	$35,953	$57,856	219	237.85%	302,913	$0.00637
13	58	$112,059	$183,951	$296,009	237	511.92%	1,039,679	$0.00949
14	525	$54,954	$90,210	$145,164	398	175.83%	1,116,847	$0.00433
15	313	$74,595	$122,452	$197,047	324	203.52%	1,228,304	$0.00535
Mean	291	$33,251	$54,585	$87,836	215	226.05%	454,950	$0.00644

would originate or terminate there and because of the incremental increase in northbound and southbound movements that would simply pass through the area. If we assume that all downbound grain, except for the small amount diverting to Texas or the PNW, would pass through the St. Louis area and consider the volume of other commodities that would move to or from the area as a part of a multi-modal movement, the additional rail tonnage within the St. Louis area could amount to as much as 65 million tons a year. Moreover, nearly half of that tonnage would be grain destined for transloading to barge at St. Louis. The impact of both the general increase in traffic and the specific increase in grain transloadings seem worthy of investigation.

Table 4.7 provides a summary of 1996 rail traffic that either originated or terminated in the St. Louis Bureau of Economic Analysis (BEA) area. In addition to this traffic, waybill statistics indicate that another 20 million tons were interchanged between carriers in the area. Finally, an application of the routing algorithm described in Section 3 suggests that perhaps another 20 million tons of railroad traffic passed through the area on a single carrier, destined for some other location.[25] In total, it appears that, in 1996, the railroad infrastructure in and around St. Louis handled roughly 100 million tons of revenue traffic (or approximately 5% of the U.S. total). Clearly, any situation that places an additional 30-60 million tons of traffic at this terminal location could necessitate the addition of new capacity.

Table 4.7

Two Digit Standard Transportation Commodity Code	*1996 Tons Originating or Terminating in the St. Louis BEA Area*	*Two Digit Standard Transportation Commodity Code*	*1996 Tons Originating or Terminating in the St. Louis BEA Area*
1	16,186,418	32	1,655,274
9	920	33	650,100
10	3,960	34	33,096
11	24,735,538	35	3,380
14	1,597,760	36	49,352
20	3,620,256	37	801,651
21	3,000	38	800
22	1,720	39	3,800
23	1,680	40	804,266
24	2,136,168	41	18,320
25	8,440	42	103,440
26	1,495,316	43	15,200
27	13,760	44	32,560
28	5,125,469	45	31,760
29	1,497,498	46	1,978,240
30	4,080	48	53,240
TOTAL - ALL COMMODITIES			62,666,462

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[25] It is also possible that some portion of the 62 million tons originating and terminating in St. Louis were actually interchange movements where separate waybills were prepared under Accounting Rule 11.

While a 30-60% increase in traffic volume would tax the entirety of the regional infrastructure, the two elements that are currently blamed most often for congestion problems include the capacity of the two railroad bridges that span the Mississippi River at St. Louis and the ability of the Terminal Railroad Association of St. Louis (TRRA) to expeditiously interchange traffic between carriers. Thus, the extent to which diverted traffic might cause significant congestion or necessitate costly infrastructure modifications is very much a function of whether that diverted traffic would be required to cross the Mississippi at St. Louis and whether or not it would require interchange.

Apart from general issues of rail capacity, the above discussion makes it clear that it would be necessary to transload an additional 30 million tons of grain from rail to barge each year. Waterborne commerce records indicate that roughly 10 million tons of grain are loaded to barge on the reaches of the Mississippi below Lock and Dam 26 and above Cairo, Illinois, with the vast majority of this being loaded in or around the St. Louis area. Thus, the diversions based on current economic conditions would require a tripling of barge loading capacity within the region.

Three important points may serve to mitigate the import of the above discussion. First, as noted in Section 2, the continuing pattern of railroad consolidations provides rail carriers with considerably more latitude in developing routing alternatives that bypass congested terminal facilities. Consequently, while current practices indicate a significant increase in terminal activity in and around St. Louis if navigation cannot economically accept its share of new traffic, it may be possible for a measurable portion of traffic to be routed so as to avoid St. Louis. Next, an examination of the transportation rates that serve as the basis for diversion calculations reveals that the benefit to St. Louis rail/barge routing as compared to an all-land movement is very often marginal. That is to say that a very small increase in the cost of moving traffic over St. Louis, may lead to an all-land diversion that need not include St. Louis in the routing. For example, even a modest increase in the cost of the St. Louis rail/barge alternative would could divert export corn movements toward Kansas City and a Texas Gulf export destination. Finally, policy-makers must realize that a doubling of output growth will necessitate both private and public expenditures on new capacity. The question is not *whether* money will be spent, but is instead *where* the additional expenditures will provide the most efficient transportation. Even considering these caveats and qualifications, however, it is clear that the availability of railroad capacity in and around St. Louis is an area of concern.

SECTION 5

CONCLUSIONS AND SUMMARY COMMENTS

Those familiar with the empirical data and methods commonly used in transportation economics are sure to conclude that the above analysis pushes the available data to the limits of their usefulness and, simultaneously, employs myriad simplifying assumptions that are routinely violated within the day-to-day world of transportation. The ambitious nature of this investigation combined with the paucity of useful information simply demanded that we be both inventive in our approach and accepting of a certain level of imprecision. Thus, the conclusions we draw from this study rest on a relatively fragile analysis. However, noting this qualification, we remain convinced that both the methods and results reported above represent the best generalized treatment of railroad capacity currently available. Moreover, we are sufficiently confident in the empirical results to urge their incorporation into the more traditional economic analyses that are being conducted with respect to Upper Mississippi River navigation.

The transportation infrastructure that is the focus of more broadly framed policy questions is the product of a remarkably dynamic and resilient spatial equilibrium in which producers, transportation providers, and downstream consumers continually modify their behaviors to reflect changing market conditions. Thus, any number of exogenous changes could disrupt the interrelated predictions that form the basis for this rail capacity analysis. If, however, future events and market outcomes unfold in ways that are not radically different from those foreseen at the present time, then the analysis presented above, in combination with other work on the Upper Mississippi, supports the following conclusions:

- Input usage and output growth in the Upper Mississippi basin will necessitate the addition of new transportation capacity over the coming decades.

- Given the current capacity embodied within the Upper Mississippi navigation system, as well as the observed set of operating practices, the evolving incremental increases in transportation demand will place considerable levels of new traffic on the nation's interior rail system.

- In most cases, the line-haul segments that, together, form the routes over which expanded traffic flows must be accommodated can be modified to do so without placing an undesirable upward pressure on competitively developed railroad rates.

- At least in the case of the Upper Mississippi basin, concerns regarding terminal congestion and the adverse effects this congestion may have on railroad pricing should be limited to operations in and around St. Louis.

- With the possible exception of movements to, from and through St. Louis, the traditional Corps assumption of ample alternative modal capacity is valid for use in the analysis of Upper Mississippi navigation.

In order that there be no confusion, we wish to explicitly note that these results *do not* imply that Upper Mississippi River navigation is without economic benefit. They do, however, support the traditional methods by which national economic development benefits are calculated. The Corps' Principles and Guidelines explicitly instruct analysts to assume sufficient modal capacity unless there is compelling evidence to the contrary. The results of the current analysis do not constitute such evidence.